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Laboratory and pilot plant flotation studies on settling pond coking coal fines and its utilization for metallurgical purposes

Most of the Indian coking coal washeries were installed during the period 1960-1980 where the design of the washery was based on relatively easy or moderately difficult washing coking coals, mined in the eastern and western part of Jharia coalfields. The coal fines below 0.5 mm were not processed and though enriched in vitrinite content, nowadays the fines cannot be mixed directly with clean coal due to their high ash content (more than 25%) and of high percentage of silica content.

Due to an increase in opencast mechanized mining of coals, quality of the coal fines deteriorated and they need to be beneficiated before blending with the coarse coals. Some of the washeries installed fine coal treatment plants, but due to varied reasons these circuits were not operated as a result, huge quantity of unwashed coal fines is left as such and discharged to nearby ponds or lagoons, and in the process they had been accumulated in adjoining settling ponds causing environmental pollution and are being sold to domestic market for use in non-metallurgical purposes.

The coking coal fines constitute vitrinite content, which is a vital ingredient for metallurgical purposes. Hence, if these coal fines are beneficiated, they may add to the overall quality of the clean coal. In this paper attempt has been made to beneficiate the accumulated coal fines through laboratory flotation tests vis-a-vis pilot plant studies to generate maximum amount of cleans from settling pond coal fines suitable as blend for metallurgical coke making.

Introduction

The coal beneficiation process adopted by central coal washeries produce approximately 1.6 million tonnes of slurry annually. This slurry or basically the coal fines is yet to be beneficiated in large scale flotation units, which are still to be made operational. This results in the accumulation of slurry/fines and creates tremendous problem for the existing washeries. These huge quantity of potentially enriched coking coal material is virtually wasted, which, if properly beneficiated could have augmented the supply of scarce coking coal to the steel industry.

A number of washeries were installed during 1960-1980 with CFRI process design using relatively easy or moderately difficult washing coking coals, mined in the eastern and western part of Jharia coalfields. Through the passage of time, the original linkage to the washeries has undergone a sea change with regard to property of feed coal, both in terms of mineral matter and washability characteristics. The above washeries were designed to wash coarser coals up to 0.5 mm only with jig and heavy media circuits to produce metallurgical cleans at 17% ash level with the then available better quality upper seam coals. Thus in those days the coal fines below 0.5 mm were not processed and only it was mixed with clean coals produced from coarse coal washing circuits.

At present due to opencast mechanised mining of coals from lower seams of Jharia coalfield, the quality of coal produced has become inferior compared to upper seam coals due to the association of undesirable mineral matter. Moreover, if the raw coal fines below 0.5 mm generated are not processed, the coarser clean coals cannot be used for metallurgical purpose by simple blending the unwashed coal fines as was used for upper seam coals owing to lack of requisite quantity of reactive component for coke making and as the fines contain high ash (more than 25%). Thus in most of the washeries, the unwashed fines below 0.5mm are sent to the thickener or drained to nearby slurry ponds. Due to absence of slurry beneficiation plant in the coking coal washeries, the generated slurries in the processes had been accumulated in adjoining settling ponds thereby causing environmental pollution and are being sold to domestic market for use in non-metallurgical purposes.

A better integrated option of reducing the pollution is to search for an optimum combination of different physico-chemical and gravity processes for beneficiation of the coal slurries for value addition as well as environmental protection. Detailed laboratory and pilot scale studies will help understanding the characteristics of the coal fines lying

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in waste settling ponds and develop a suitable flow sheet which may provide valuable inputs for recovering additional cleans, which otherwise discharged as waste and invites pollution problems in the surrounding areas of the washeries.

The treatment of coal fines by various beneficiation routes is justified to the fact that they are having better coking propensity and it is a valuable prerequisite in preparing cleans for metallurgical coke. Though enriched in vitrinite content, the fines cannot be mixed directly with clean coal due to their high ash content (more than 25%) and of high percentage of silica content. The slurry needs to be washed through suitable coal cleaning technology for enrichment of coking propensity and for utilization of total cleans as high valued component for coke making.

Sublik et al [1983] attempted to explain the influence of ultrafine coal particles (below 0.06 mm) on the floatability of three phase system constituting solid, liquid and gas (normally air). Aeration and bubble characteristic for the recovery of fine particles were studied by Jameson [1983]. Kalyan Sen et al [1984] studied the effect of varying both the collector and frother doses on the flotation products which was significant to optimize the flotation circuit. A recent published report by Yoon [1984] said that coal particles below (approximately) 38 micron in diameter are difficult to float and consume more quantity of reagents. N.Schapiro et.al.[1964] studied the dependence of coke quality on petrographic characteristics of coal, i.e. maceral composition including mineral content and rank of vitrinite, in terms of mean reflectance and reflectance distribution. The paper highlights the studies carried out on coal fines through laboratory and pilot plant flotation tests.

Experimental process

The process adopted for the production of low ash good quality coking coal fines in coal beneficiation plant is a specially designed froth flotation system. The basic physical properties influencing the processing behaviour of slurry are: particle size and shape, density, capillarity (surface pressure and absorption pressure), electrical conductivity, ash content, flammable material content and calorific value. Batch flotation studies were carried out in Denver D12 sub aeration flotation machine. The coal slurry at a pulp density of 30-35% is conditioned with diesel oil at the rate of (1.0 -1.25 kg/t) of coal. The diesel oil termed as collector is dispersed, collided and adsorbed on to the coal surfaces due to mechanical agitation in the conditioner. In some installations, the collector is emulsified before feeding to conditioner. The conditioned pulp is then diluted to the desired level (10 to 15%) in the pulp density adjusting tank (PDAT) and then brought to the flotation cell. Frother, normally MIBC is added at the rate of 0.15 - 0.25 kg/t of coal. The conditioned coal particles attach with the air bubbles and reach to the top of the cells to be skimmed off. The impurities in the form of tailings are taken out from the cell. The beneficiated coal fines in the form of froth are collected and vacuum filtered. The samples were dried, weighed and analyzed for ash.

Laboratory release analysis

The release analysis study was conducted on below 0.5mm size coal using the standard test procedure. In order to determine the floatability of the coking coal fines, the release analysis test developed by Dell was carried out. The schematic of release analysis is shown in Fig.1. The test results are presented in Table 1 and depicted in Fig.2.

The objective of release analysis procedure is to separate perfectly ground ore/coal to a number of fractions by flotation so that the degree of liberation or 'state of release' of the ore/ coal can be seen. Its purpose is thus the same as that of a float and sinks analysis in gravity separation.

The simplified release analysis procedure consists of two stages. The first stage objective is to completely separate the

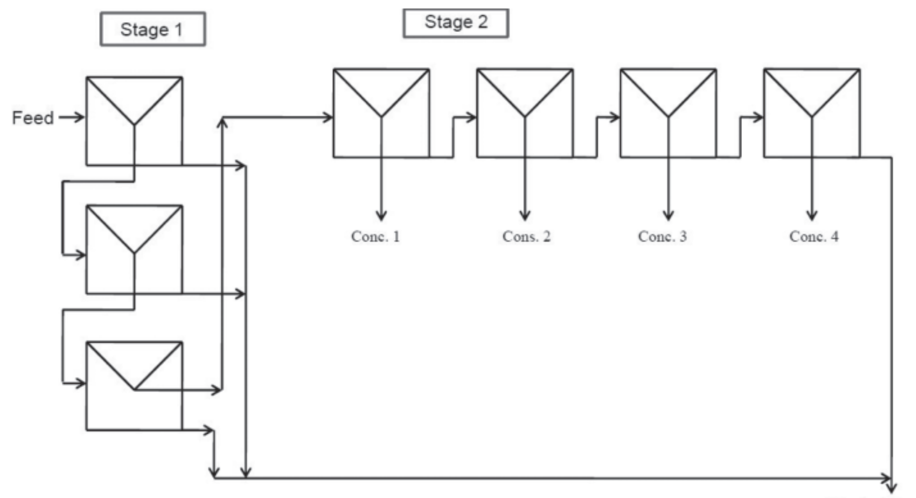

Fig.1 Schematic of release analysis process

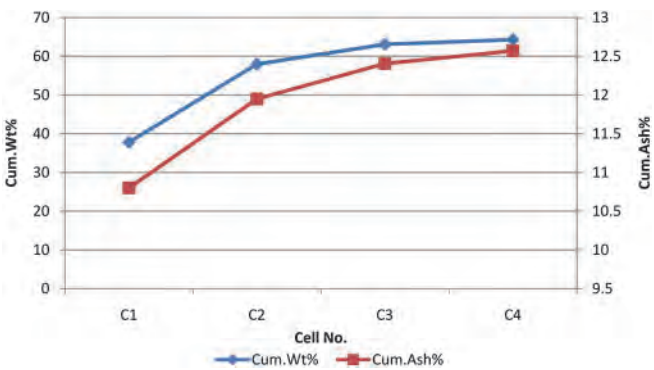

Fig.2 Kinetic analysis (laboratory flotation)

TABLE 1: RELEASE ANALYSIS

	Wt %	Ash %	M %
C1	37.8	10.8	1.4
C2	20.2	14.1	1.5
C3	5.1	17.6	1.3
C4	1.2	21.2	1.2
Tailings	35.7	61.2	1.9
	100.0	29.9	1.9
	64.3	12.6	1.4

floatable material from the non-floatable material by repeated flotation of the concentrate under intense flotation conditions (i.e., high aeration rate and impeller speed). The second stage objective is to separate the floatable material from the first stage into fractions beginning with the low-recovery, high-grade material and proceeding to the high-recovery, low-grade fraction. The concentrate from the first stage is floated at several impeller speeds and aeration rates of steadily increasing intensity. Under these flotation conditions, concentrates of decreasing quality are collected and a release curve is generated. Therefore, the fractionation is dependent on the flotation intensity and not the timing of the concentrate collection.

Pilot plant testing

About 10 tonnes of coal slurry sample was processed in the flotation plant. The coal slurry was first conditioned in the conditioner (Fig.2) with diesel oil at the rate of 1.5 kg/t as collector reagent. The conditioned slurry was then fed to the bank of flotation cells (Fig.2) where the frother MIBC was added at the rate of 0.5 kg/hr. The froth was collected as cleans and dewatered in the drum filter, while the tailings was sent to the tailings sump. Samples of clean coal from different flotation cells and combined tailings were collected at regular intervals and analyzed for its ash content and the data is shown in Table 2. It was observed that the yield of concentrate at desired ash level is almost at par with the release analysis data.

TABLE 2: PILOT PLANT FLOTATION DATA

Cell no.	Concentrate	
	Wt %	Ash %
C1	32.4	13.2
C2	14.8	15.1
C3	8.9	17.4
C4	4.5	18.4
Total cleans	60.6	14.7

Results and discussion

The coking coal fines collected from settling pond of an operating coal washery were air-dried and processed to get test samples for different characterization studies. The representative samples were characterized w.r.t proximate analysis, carbonization tests and petrography analysis.

Characterization tests of raw coal as depicted in Table 3 revealed that ash percentage of coal is 30.0% and moisture percentage (on as received) of the coal is 1.2%. The sample tested is medium volatile in nature, the VM% being 19.1. The coking propensities of the coal fines seem to be good in quality. The swelling index (CSN) is hardly 3.0 which may be termed as good coking coal and LTGK is C. The petrographic analysis from Table 4 shows the vitrinite content is 41.1% and the inertinite is 31.2%. The reflectance of the coal fines is 1.0% which indicates the maturity of coal.

TABLE 3: PROXIMATE AND CARBONIZATION DATA OF RAW COAL

Proximate				Carbonization	
Moist %	Ash %	V. M %	F.C %	CSN	LTGK
1.1	30.5	18.9	49.5	3	C

TABLE 4: PETROGRAPHIC ANALYSIS OF RAW COAL

Petrographic analysis (macreal comp. % v/v)					Mean
Vitrinite	Semi-vit	Exinite	Intertintie	Min. matter	Ro%
41.1	3.2	0.4	31.2	24.1	1.0

The screen analysis on the coal fines collected from washery was carried out in the laboratory at sizes 500, 250, 125 and 63 micron. The results are presented in Table 5. It may be observed from the results that the quantity of ultrafines (-63micron) is 24.5 per cent which may adversely affect the processing of the raw material.

TABLE 5: SCREEN ANALYSIS

Size (micron)	Wt %	Ash %
500	7.9	20.1
500-250	25.5	25.3
250-125	25.8	28.6
125-63	16.3	33.3
-63	24.5	37.6
	100.0	30.1

Characterization of the clean coal

Characterization tests of clean coal as depicted in Table 6 revealed that ash percentage is 14.7% while the moisture percentage is 1.1%. The volatile matter improved to 24.9% compared to 18.9% in the raw coal. The coking propensities of the clean coal improved to that of the raw coal CSN being 5 and LTGK coke type being G4. The petrographic analysis from Table 7, shows the vitrinite content improved to 72.3 compared to 41.1% in the raw coal. The reflectance is high having the value of 1.10% which shows the maturity of coal.

It may be seen from the Table 7, that the quality of the clean coal improved with all respects and may be used for metallurgical purpose. The V-type distribution is shown in Fig.3.

Fig.3 Pilot scale flotation cells (400 kg/hr capacity)

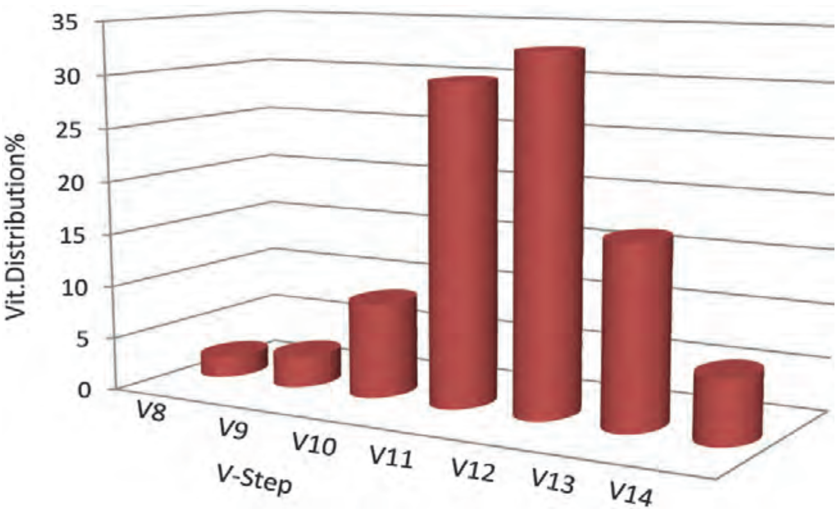

Fig.4 V Step distribution of the cleans

TABLE 6: PROXIMATE AND CARBONIZATION DATA OF CLEAN COAL

Proximate				Carbonization	
Moist %	Ash %	V. M %	F.C %	CSN	LTGK
1.1	14.7	24.9	59.3	35	G4

TABLE 7: PETROGRAPHIC ANALYSIS OF CLEAN COAL

Petrographic analysis (macreal comp. % v/v)					Mean
Vitrinite	Semi-vit	Exinite	Intertintie	Min. matter	Ro%
72.3	4.0	2.0	10.8	10.9	1.1

The V step distribution from Fig.4 shows that the V9 to V13 constitute of 92% which indicates that the clean coal may be used as a coking blend for coke making.

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